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Forage systems for cow-calf production in the Appalachian region[1]

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ABSTRACT: Small cow-calf operations are common in the Appalachian region. Tall fescue [*Lolium arundinaceum* (Schreb.) S. J. Darbyshire] is the dominant forage in these systems for direct grazing as well as for stockpiling. The present study was conducted from 2001 to 2005. A total of 108 Angus and Angus crossbred cows were allotted randomly to 6 forage systems and then to 3 replicates within each system. In brief, system 1 had a stocking rate of 0.91 ha/cow in a Middleburg 3-paddock (A, B, and C) system. System 2 was similar to system 1 except for a stocking rate of 0.71 ha/cow. A stocking rate of 0.71 ha/cow also was used in systems 3 through 6. All A paddocks had tall fescue, whereas B paddocks had tall fescue/white clover (*Trifolium repens* L.) except in system 6, which had tall fescue/lespedeza [*Lespedeza cuneata* (Dum. Cours.) G. Don]. System 3 evaluated a 2-paddock (A and B) rotational grazing system, and system 4 evaluated a 3-paddock (A, B, and C) rotational grazing system, with paddock C containing orchardgrass (*Dactylis glomerata* L.) and alfalfa (*Medicago sativa* L.). Systems 5 and 6 differed from system 2 in the areas of paddocks B and C as well as in the forage mixtures used. In paddock C, system 5 had switchgrass (*Panicum virgatum* L.) and system 6 had tall fescue and birdsfoot trefoil (*Lotus corniculatus* L.). System 1 had the greatest average herbage availability from weaning until breeding ($P < 0.05$) with the least amount of hay fed ($P = 0.03$) when compared with the remainder of the systems. Differences ($P > 0.05$) in percentage of ground cover were not detected among systems. There was no year × system interaction effect on the cow or calf performance variables evaluated and no treatment effect on cow performance variables. There was a treatment effect on calf performance variables. System 2 produced the greatest adjusted weaning weight, kilograms of calf weaned per hectare, and kilograms of calf per kilograms of cow at weaning ($P < 0.05$). Numerical ranking for total calf production per hectare from the greatest to least was system 2, 6, 3, 5, 4, and 1. Systems evaluated did not affect cow performance although differences in calf performance and overall productivity of the systems were observed.

Key words: Appalachia, beef cattle, cow-calf system, forage, tall fescue

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INTRODUCTION

Hill land, characteristic of much of Appalachia, is ideally suited for grassland-based beef production. In West Virginia (WV) and Virginia (VA), some 1.7 million ha are in pasture (USDA, 1998). Grazing systems over a 12-mo period in temperate regions are usually based on cool-season grasses and legumes (Allen, 1988). Blaser et al. (1977b) developed year-round, all-forage cow-calf systems based on 3 paddocks of perennial cool-season forages by using a constant area per cow-calf unit. Year-round forage systems provided for the changing nutritional status of beef cows while calves had continuous access to high-nutritive-value forages via creep grazing adjacent paddocks within the system.

Extending the grazing season by using stockpiled perennial forages in the fall and winter reduces the amounts of hay required for winter feeding of beef cattle (Hitz and Russell, 1998). Stockpiled tall fescue provides high-quality forage during late fall and early

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winter because of the accumulation of nonstructural carbohydrates and concomitant lowering of fiber levels of stockpiled tall fescue during the fall (Brown et al., 1963).

Blaser et al. (1986) reported that forage availability and the nutritive value of cool-season pastures follow a sine curve pattern, increasing in late winter, becoming extremely high in spring and early summer, declining rapidly during mid- to late summer, and increasing in early fall. The summer decline in overall nutrients coincides with increased nutritional requirements of spring-calving cow-calf pairs, especially calves (NRC, 1996). Cows are starting to decline in milk production, and calves are more dependent on the available forage to meet their requirements. As a result, weaning weights of calves and beef production per cow or per hectare can be compromised. The objective of the present study was to compare stocking rate, grazing management, and supplemental forages within year-round, fescue-based cow-calf systems.

MATERIALS AND METHODS

This study was conducted from 2001 to 2005 at the Shenandoah Valley Agricultural Research and Extension Center (latitude: 37°56′ N; longitude: 79°13′ W; elevation: 537.4 m) to investigate forage systems for beef cow-calf pairs. All procedures were approved by the Virginia Tech Animal Care Committee.

Site Description

The site was composed primarily of silt loam soils. Three replicates (blocks) of 6 forage systems (Figure 1) were established on approximately 82 ha of land in a randomized complete block design. The core of one of the replicates was primarily Frederick-Christian silt loams, 7 to 15% slopes, eroded. These are fine, mixed, semiactive, mesic Typic Hapludults and Typic Paleudults. The second replicate was on the same types of soils with other types, namely, Frederick-Rock outcrop complex and some Bookwood silt loams, associated with the Frederick-Christian type. Bookwood soils are fine-loamy, mixed, mesic Ultic Hapludalfs. The third replicate was primarily a Frederick-Rock outcrop complex with some Fluvaquents.

Description of Animals

Initially, 108 Angus and Angus crossbred cows were blocked according to age and BW and allotted at random within blocks to 6 forage systems (18 cow-calf pairs per system, divided in 3 replicates of 6 cow-calf pairs in each of the systems). Cows remained in the respective systems throughout the experiment unless they were replaced because of failure to produce a calf or because of disease, injury, or death. The mean cow age was 5.1 ± 0.45 yr. A second herd was managed similarly on site and was used as a source of replacement cows, if needed. Replacement cows were selected for the greatest similarity to those leaving the herd. Selection criteria included age, BW, and BCS.

Forage Systems

Stocking rate was the number of hectares of the whole system available for each cow. The Middleburg system consists of 3 paddocks, as described by Blaser et al. (1977a), and is based on 1 large paddock (45% of the system area, designated paddock A in the current experiment) and 2 smaller paddocks (55% of the system area, designated paddocks B and C in the present experiment). All systems had endophyte-infected tall fescue as the primary forage in paddock A, which was used for stockpiling and for spring, late fall, and winter grazing. Alternate forages used in paddocks B and C included red and white clover, orchardgrass, switchgrass, sericea lespedeza [*Lespedeza cuneata* (Dum. Cours.) G. Don], alfalfa, and birdsfoot trefoil. These paddocks were used for creep grazing, hay production, and cow grazing while stockpiling paddock A. For rotational grazing systems 3 and 4, each paddock was subdivided into 5 subpaddocks and cows were moved when the forage supply became limited (less than 10 cm of canopy height). All systems were managed for maximal grazing days and minimal days of hay feeding. All pastures were fertilized each spring (March to April) according to soil tests (Virginia Tech Soil Testing Laboratory, Blacksburg, VA). Nitrogen was applied at 90 kg/ha in August on the A paddocks for stockpiling.

Forage systems (Figure 1) were as follows:

System 1: 0.91 ha/cow. Middleburg 3-paddock system. Paddock A (45% of the area) contained tall fescue and was used for spring, summer, late fall, and winter grazing; paddock B (35% of the area) contained tall fescue/clover and was used for creep grazing, hay, and late summer and fall grazing; paddock C (20% of the area) contained tall fescue/clover and was used primarily for creep grazing, hay, and late summer and fall grazing. Hay was produced from paddocks B and C. While these paddocks were accumulating forage, grazing in the system was concentrated in paddock A. After hay was produced, paddocks B and C were used alternatively for creep grazing and late summer and fall grazing. Paddocks A, B, or C were not further subdivided.

System 2: Same as system 1 except with a stocking rate of 0.71 ha/cow.

System 3: 0.71 ha/cow. Two-paddock (A and B) rotational grazing. Paddock A (45% of the area) had forage similar to that in system 1. Paddock B (55% of the area) contained tall fescue/clover and was used for creep grazing, hay, and summer, fall, and winter

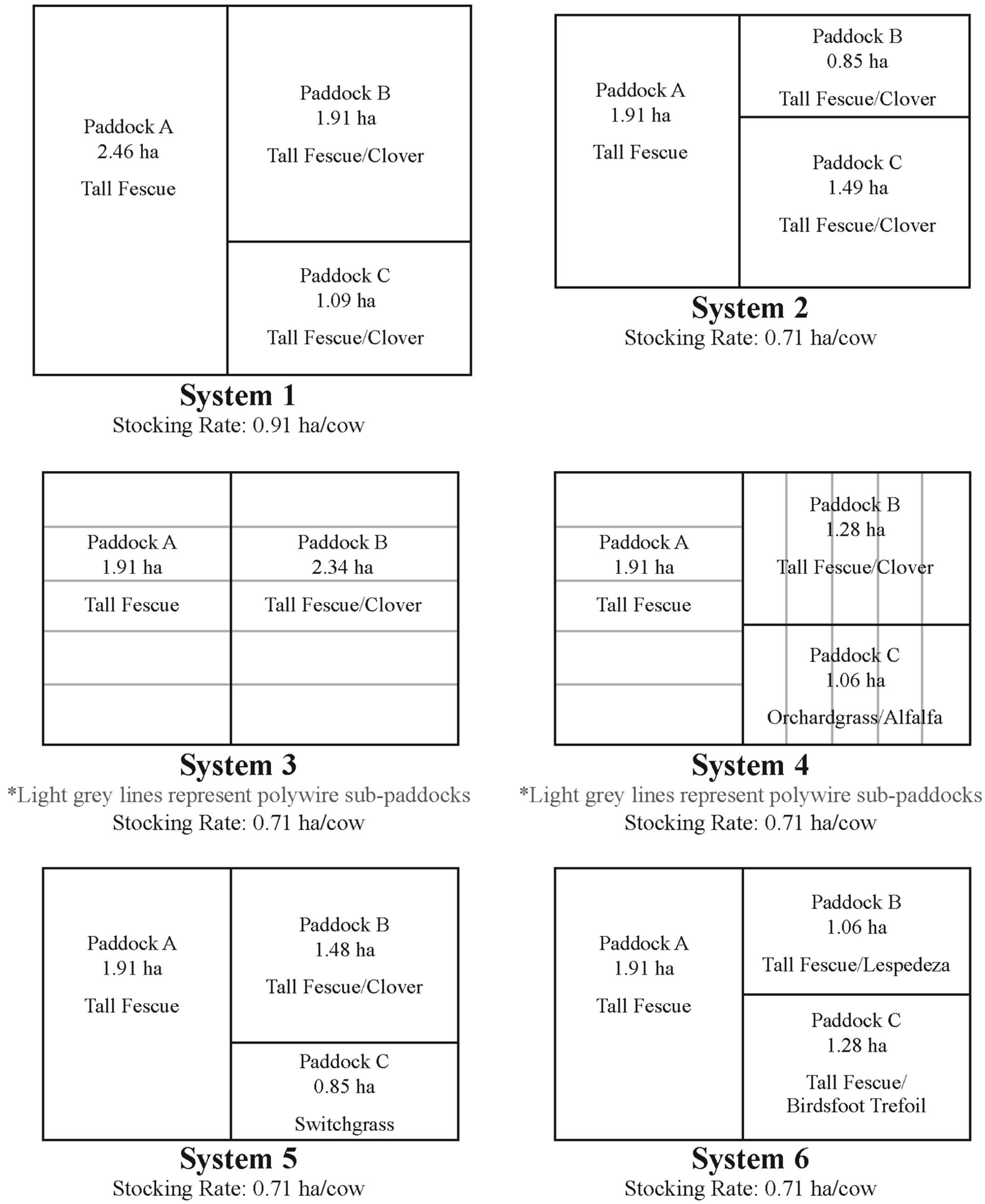

Figure 1. Diagram of the 6 forage systems evaluated. See descriptions in the text.

grazing. Each of the paddocks (A and B) was subdivided into 5 subpaddocks (Figure 1), which were rotationally stocked. Paddock A was grazed before moving animals into paddock B.

System 4: 0.71 ha/cow. Three-paddock (A, B, and C) rotational grazing. Paddock A (45% of the area) contained tall fescue and was used for spring, summer, late fall, and winter grazing; paddock B (30% of the area) contained tall fescue/clover and was used for creep grazing, hay, and late winter, summer, and early fall grazing; and paddock C (25% of the area) contained alfalfa/orchardgrass and was used for creep grazing, hay, and early spring, midsummer, and late fall grazing. Each of the 3 paddocks (A, B, and C) was subdivided into 5 subpaddocks and grazed during the periods of time described previously.

System 5: 0.71 ha/cow. Middleburg 3-paddock system. Paddock A (45% of the area) contained tall fescue and was used for spring, summer, late fall, and winter grazing; paddock B (35% of the area) contained tall fescue/clover and was used for creep grazing, hay, and early fall grazing; and paddock C (20% of the area) contained switchgrass and was used for summer grazing for cows while calves creep grazed tall fescue/clover pastures.

System 6: 0.71 ha/cow. Middleburg 3-paddock system. Paddock A (45% of the area) contained tall fescue and was used for spring, late fall, summer, and winter grazing; paddock B (30% of the area) contained tall fescue and lespedeza and was used for creep grazing, hay, and summer and early fall grazing; and paddock C (25% of the area) contained tall fescue and birdsfoot trefoil and was used for creep grazing, hay, and early spring, midsummer, and late fall grazing.

Herbicide Application and Establishment of Pastures

The pastures consisted predominantly of endophyte-infected tall fescue before the establishment of research pastures. Other forages included quackgrass [*Elytrigia repens* (L.) Desv. ex Nevski], foxtail (*Setaria* spp.), and crabgrass [*Digitaria sanguinalis* (L.) Scop.], among others. In the fall of 1999 and spring of 2000, Paraquat dichloride (1,1′-dimethyl-4-4′-bipyridinium dichloride; Gramoxone, Syngenta, Wilmington, DE) at 157 g of active ingredient/ha and Glyphosate (*N*-phosphonomethyl glycine; Round-up, Monsanto, St. Louis, MO) at 570 g of active ingredient/ha were used to suppress or kill existing forages in an effort to establish the desired species in the pastures. After the establishment year, 2,4-D-isooctyl(2-ethylhexyl)ester of 2,4-dichlorophenoxyacetic acid (878 g of active ingredient/ha) and Banvel [MicroFlo Company LLC, Memphis, TN; dimethylamine salt of dicamba(3,6-dichloro-*o*-anisic acid); 302 g of active ingredient/ha] were applied to control broadleaf weeds, thistle (*Cirsium* spp.), and in summer (July) to control horse nettle (*Solanum carolinense* L.) in pastures without legumes. The pastures were seeded with the following in fall of 1999 and spring of 2000: 16 kg/ha of 'Kentucky-31' endophyte-infected tall fescue, 2.2 kg/ha of 'Will' ladino clover, 20.2 kg/ha of 'Amerigraze 401' alfalfa, 11.2 kg/ha of 'Benchmark' orchardgrass, 27 kg/ha of 'AU Grazer' sericea lespedeza [*Lespedeza cuneata* (Dum. Cours.) G. Don], and 11.2 kg/ha of 'Dawn' birdsfoot trefoil and 67.2 kg/ha of 'Cave-N-Rock' switchgrass. The drill used was a John Deere 1560 (Deere and Co., Moline, IL) no-till drill, 3 m of planting width, with large and small seedboxes.

Fertilization Strategy

In 2000, all A paddocks were fertilized with 45 kg/ha of N, whereas paddocks B and C received 28 kg/ha of N. Because of the strong stand of clover in some of the paddocks, fescue did not grow well and was reseeded in the fall of 2000. Some of the pastures were again sprayed the next spring (2001) and all of the pastures were reseeded. The grass and legumes were both planted together in the spring. Nitrogen was applied annually thereafter after soil tests were performed, according to the recommendations of a forage agronomist. In brief, paddocks A in all systems were fertilized yearly in the spring with 45 to 79 kg/ha of N. Paddocks B, which were composed of fescue/lespedeza or birdsfoot trefoil, received 45 and 56 kg/ha of N in the spring of 2003 and 2004, respectively. The reason for this difference was that in 2003 a better stand of the legumes was present. In 2004, the presence of legumes was reduced; thus, more N was applied to paddocks containing legumes. Paddocks C, composed of orchardgrass and alfalfa, were not fertilized. Finally, paddocks C, containing switchgrass, were fertilized with 45 to 67 kg/ha of N in the spring of each year.

Endophyte Status of Tall Fescue Pastures

Tall fescue plants were tested for the presence of the *Neotyphodium coenophialum* (Morgan-Jones and Gams) Glenn, Bacon, and Hamlin comb. nov. (Glenn et al., 1996) fungus in 1999 (Fescue Diagnostic Center, Auburn University, Auburn, AL) and with ELISA kits (Agrinostics, Ltd. Co., Watkinsville, GA) in 2003. Six samples per replicate were taken randomly from the area where the different systems were going to be established. Average endophyte infection was 88.5%, with a range between 67 and 100%. In 2003, 20 tillers were taken from each of the 45 paddocks with endophyte-infected fescue. Mean infection rate was 70.8 ± 38%.

Hay Production

Calves creep grazed pastures (B and C paddocks alternatively) from July until weaning in October. Hay was harvested each spring (May to June) from the B and C paddocks. Individual round bales were labeled with the forage system and subpaddock origin from which they came and were individually weighed and sampled when fed. Hay produced within a given system was fed ad libitum in round bale feeders to the cows in that same system. Hay was fed when there was deep snow cover or when the available forage mass was estimated by visual observation to be less than 7.5 cm of canopy height. No additional supplements were used.

Herd Management

Cows were bred to calve in a 65-d period between late February and early May. At 10 to 21 d (depending on year) before breeding, cows were vaccinated against infectious bovine respiratory syncytial virus, infectious bovine rhinotracheitis, bovine viral diarrhea virus, parainfluenza, and leptospirosis (Pyramid 9, Fort Dodge Animal Health, Fort Dodge, IA). Cows were synchronized for AI (always by the same technician) with 50 μg of GnRH on d 0 (Cystorelin, Merial Ltd., Duluth, GA), 25 mg $PGF_{2\alpha}$ (Lutalyse, Pfizer Animal Health, New York, NY) on d 7, and 100 μg of Cystorelin at the time of breeding on the morning of d 10. After 14 d, a randomly assigned yearling cleanup bull was turned out with each group of cows. Semen (AI) from Angus sires (selected from commercial companies) and 18 cleanup bulls (leased from seedstock producers in VA) were used. All bulls were selected based on EPD for birth weight, milk, weaning, and yearling weight. Across years, the average EPD for weaning weight, yearling weight, and milk EPD were 41, 82, and 26, respectively. Within 45 to 60 d after the end of the breeding season, cows were rectally palpated for pregnancy diagnosis by a veterinarian and conception date was estimated. Open cows were culled 2 wk later and replaced with a pregnant cow (preferably from AI) of similar age, BW, and BCS from a similar herd. At birth, all calves were ear-tagged, weighed by using a portable scale (LBS Scales, LBS Inc., Garden City, KS), and given 500,000 IU of vitamin A and 75,000 of vitamin D (Vedco, St. Joseph, MO). Males were castrated by using elastic bands (castrating bands, Ideal Instruments, Nasco, Fort Atkinson, WI). Calf and cow weights and cow BCS (scale 1 to 9; Richards et al., 1986) were determined at breeding (May 1) and weaning (October).

At 3 to 5 wk before weaning, steer and heifer calves were vaccinated against bovine respiratory syncytial virus, infectious bovine rhinotracheitis, bovine viral diarrhea virus, and parainfluenza (Pyramid 4, Fort Dodge Animal Health, Fort Dodge, IA) and clostridial disease (Vision 7, Intervet, Boxmeer, the Netherlands). At weaning, calves were treated with pour-on anthelmintic (Cydectin, Fort Dodge Animal Health, Fort Dodge, IA). Fly control was maintained with pour-on lambdacyhalothrin (Saber, Schering Plough Animal Health, Union, NJ) administered as needed during the fly season.

Cows and calves were allowed ad libitum access to water and a mineral and vitamin supplement (Ca 11.8%, P 6.5%, Mg 11.2%, Zn 0.51%, Cu 0.25%, I 0.014%, Mn 0.40%, Se 0.012%, and vitamins D_3 and E at 185,600 and 1,100 IU/kg, respectively; King AG Products Inc., Pulaski, VA).

Forage Sampling and Analysis

Over the growing season, forage mass was determined at monthly intervals in paddocks where cattle were grazing (for systems 1, 2, 5, and 6) or immediately before cattle entered into a new paddock (systems 3 and 4). However, for the former, every time cattle were moved to a new paddock, forage was sampled in this new paddock. In the rotational systems (systems 3 and 4), forage mass was determined when cattle were moved from one subpaddock to the other. Standing herbage mass was estimated by randomly harvesting three 1-m strips cut to a 2.5-cm stubble height with a rotary mower with bagger attachment (Model HR215, American Honda Motor Company, Duluth, GA). Four strips were harvested from continuously stocked pastures and 5 strips (1 from each of the subpaddocks) were harvested in the rotationally stocked pastures. Strips were not harvested when the standing herbage mass was less than 1,000 kg/ha by visual estimate. In June of 2004 and September of 2005, the botanical composition of all paddocks was evaluated by one of the coauthors (Dr. A. O. Abaye) by using the double DAFOR (forage species in a paddock are classified as D = dominant, A = abundant, F = frequent, O = occasional, or R = rare) scale as described by Abaye et al. (1997), which is a modification of the DAFOR scale described by Brodie (1985). In brief, within each pasture, a 5×5 m^2 area was permanently located on similar soils and slope aspects. Two quadrat samples (0.25 m^2) each were clipped from within this plot. Samples were hand separated into individual species, dried, and weighed to determine the percentage of botanical composition. At the same time, this area was visually evaluated by 3 independent evaluators for botanical composition by using the DAFOR scale with the following modifications. Individual species of grasses and legumes were ranked first as dominant, abundant, frequent, occasional, or rare. Broadleaf weeds as a total group also were given this ranking. A second DAFOR scale was then used to rank individual weed species as dominant, abundant, frequent, occasional, and rare. Visual estimates of the percentage of ground cover and the percentages of grass, legume, and weed species also were made.

Laboratory analyses were performed on all samples (forage and hay) and included DM (method 934.01), ash (method 942.05), and N (method 990.03; combustion N determination by using a PE2410 Series II Nitrogen Analyzer, Perkin-Elmer Instruments, Norwalk, CT) following AOAC (2000) standards. Levels of NDF (with the addition of heat-stable α-amylase and anhydrous sodium sulfate) and ADF (Van Soest et al., 1991; Ankom Technology Corporation, 1997) also were determined.

Statistical Analyses

Annual animal and forage data are presented in 3 periods. These 3 periods, on average, of the 4 yr were from October 23 (weaning) to April 27 (breeding), to July 31 (midsummer), and to October 23. These periods are represented as: 1) weaning to breeding (**W-B**), 2) breeding to midsummer (**B-S**), and 3) midsummer to weaning (**S-W**).

Data were analyzed by using PROC MIXED (SAS Inst. Inc., Cary, NC) as a randomized complete block design with 3 replicates. Year and period within year were the repeated measures used for the overall analysis and for within-year analyses, respectively. Replicate within forage system was the experimental unit. Pregnancy rates were analyzed by using the multivariate logistic regression of SAS, with pasture as the experimental unit. The covariance structure was best fit with the autoregressive covariance structure.

Adjusted 205-d weaning weight was estimated as [(weaning weight − birth weight)/weaning age] × 205

+ birth weight. The calf-to-cow weight ratio of a system was estimated as the coefficient between total kilograms of calf weaned and total kilograms of BW of their respective dams at weaning. Calf weaned per hectare was estimated from the coefficient between the total kilograms of calf weaned in a system and the total area of that particular system. Data were analyzed by using PROC MIXED of SAS as a randomized complete block design with 3 replicates. Year was the repeated measure and replicate within forage system was the experimental unit.

RESULTS AND DISCUSSION

Weather Data

Total monthly rainfall was recorded on site by using a weather station (WatchDog Model 900, Spectrum Technologies Inc., Plainfield, IL). Mean monthly temperature during the experiment and historical means from 1948 to 2005 for rainfall and temperature were obtained from a weather station approximately 25 km north of Steeles Tavern, at Staunton, VA (Southeast Regional Climate Center, 2006). Temperature and rainfall data are shown in Table 1. Precipitation in yr 2 from October to November and from February to September was, on average, 74% greater than the historic mean. Between May and September (late spring to summer), rainfall increased, which coincided with the high growth rate of forage (tall fescue in particular) during these months. Winter temperatures in yr 1 were above average but were below average in yr 2 and 3. During the spring and summer months, temperatures were similar to the historic mean. This was particularly important during yr 2 because of its association with high rainfall, which allowed for greater forage production. In yr 4, problems with the weather station precluded obtaining temperature data during January, February, and September.

Days on Pasture

Days on pasture refers to the number of days that cows or cow-calf pairs spent in each of the paddocks (A, B, or C, regardless of type of grazing system) and is expressed as percentage of the year (data not shown). Regardless of the grazing system, cows spent approximately two-thirds of the year in paddock A. Hay-feeding periods are included in that estimation. Paddock B in systems 3 and 6 were grazed for the most (36%) and least (13.6%) amount of time, respectively; system 3 had only 2 paddocks. In systems 3 and 4, managed with rotational stocking, cows or cow-calf pairs spent 36 and 27%, respectively, of the time in paddock B. Paddock C in system 6 was grazed most (24% of the time) compared with other systems (average of 11%) because of the shortage of forage in paddock B (tall fescue/lespedeza).

Forage Production

No system × year interaction was observed (P = 0.61), so only main effects are reported. Forage system affected (Table 2) the average herbage available (kg of DM/ha) from weaning to breeding (P = 0.041) and from breeding to midsummer (P = 0.008). In both periods, the forage available in system 1 was greater (P < 0.01) than that in systems 2, 3, and 6. These results should be expected with the lower stocking rate in system 1, compared with the other systems. The average herbage available in all 3 periods also was affected by year (data not shown). Year 4 had more (P < 0.001) herbage avail-

Table 1. Total monthly rainfall recorded at Steeles Tavern, VA, mean monthly temperature during the period from October 1, 2001, through September 30, 2005, and historical means from 1948 to 2005 for rainfall and temperature obtained at Staunton, VA

	Rainfall, mm					Average temperature,[2] °C				
Month	1[1,3]	2[1]	3[1]	4[1]	Historic mean[2]	1	2	3	4	Historic mean
October	10	118	61	38	75	13.0	12.0	11.5	12.8	12.2
November	6	143	173	98	73	10.7	6.1	10.0	8.8	6.9
December	61	57	96	71	66	5.4	0.6	1.2	2.3	1.9
January	29	45	39	89	66	3.1	−2.0	−1.6	ND[4]	0.3
February	15	167	60	36	59	3.5	−1.0	0.6	ND	1.6
March	84	86	48	83	82	6.0	8.1	7.3	3.6	5.7
April	118	96	85	102	74	12.9	11.0	11.5	11.9	11.3
May	71	161	183	103	91	15.5	15.1	19.7	14.5	16.3
June	26	132	98	38	85	22.2	19.1	20.1	21.4	20.6
July	125	140	89	133	96	23.8	22.3	22.4	23.7	22.9
August	29	207	100	66	87	23.6	23.0	20.9	23.4	22.1
September	69	356	170	7	99	19.9	17.9	18.9	ND	18.3

[1]Obtained at Steeles Tavern, VA.
[2]Obtained at Staunton, VA.
[3]Year of the study.
[4]ND = no data available.

Table 2. Average herbage available (kg of DM/ha) by period within systems and by period within year

	System[2]							
Period[1]	1	2	3	4	5	6	SEM	*P*-value, S[3]
W-B	1,590[a]	1,310[bc]	1,310[bc]	1,540[a]	1,470[ab]	1,250[c]	80.1	0.041
B-S	2,200[a]	1,770[b]	1,590[b]	1,810[b]	1,740[b]	1,570[b]	104.4	0.008
S-W	1,910	1,680	1,230	1,980	1,300	1,640	183.2	0.063

[a–c]Within a row, means without a common superscript letter differ ($P < 0.05$).

[1]W-B = period from weaning to breeding (October to April); B-S = period breeding to summer (April to July); S-W = period summer to weaning (July to October).

[2]Systems: 1 = Middleburg 3-paddock, 0.91 ha/cow, tall fescue (paddock A), tall fescue-clover (paddocks B and C); 2 = Middleburg 3-paddock, 0.71 ha/cow, tall fescue (paddock A), tall fescue-clover (paddocks B and C); 3 = 2 paddocks, 0.71 ha/cow, rotational, tall fescue (paddock A), tall fescue-clover (paddock B); 4 = 3 paddocks, 0.71 ha/cow, rotational, tall fescue (paddock A), tall fescue-clover (paddock B), orchardgrass-alfalfa (paddock C); 5 = Middleburg 3-paddock, 0.71 ha/cow, tall fescue (paddock A), tall fescue-clover (paddock B), switchgrass (paddock C); 6 = Middleburg 3-paddock, 0.71 ha/cow, tall fescue (paddock A), tall fescue-lespedeza (paddock B), tall fescue-birdsfoot trefoil (paddock C).

[3]System effect.

able than the other years (3,070, 2,700, and 2,400 kg of DM/ha for W-B, B-S, and S-W, respectively), whereas yr 1 had the least (790, 1,100, and 600 kg of DM/ha for W-B, B-S, and S-W, respectively). The low amount of herbage available during yr 1 can be partially explained by the low amount of rainfall (Table 1), which was below average in most months. The lack of rainfall in yr 1 had a greater effect on pasture production because pastures were in their first year of production. Lower DM production because of these factors can be expected (Hodgson, 1990). Conversely, DM production in yr 4 was greater because of the average rainfall during the year and the wet conditions in yr 2 and 3, which helped establish the desired forages and thus increase productivity.

Average ground cover, and forage and weed composition of pastures were determined in June 2004 and September 2005 (data not shown). Pasture evaluation was conducted during alternate seasons for a more complete evaluation of pasture health. Legumes were present in a low percentage in 2004 (average of 8%, whereas grasses constituted 83% and weeds 9% of the ground cover) and absent in 2005 because of the following. 1) In yr 2, the rainfall was above average (Table 1) and may have favored the competition legumes exerted in the tall fescue-dominated swards, explaining the appearance of legumes in all paddocks sampled. 2) The possible disappearance of the legumes in the following yr (2005) may have been due to overgrazing of legumes when they appeared in a mixed sward together with one or more grasses (Curll and Wilkins, 1982), as in this case. Ruminants tend to selectively graze for legumes, and the stocking rate as well as the lack of rest for the pasture in critical moments of the legumes' cycle may have contributed to the effect. Average ground cover was 95% for all systems, and tall fescue was the dominant forage (data not shown) in systems where it was the base forage. The average percentage of ground cover for switchgrass paddocks was 72%, and switchgrass was dominant in only 1 replicate, whereas it was abundant (together with weeds) in the other 2. In these 2 cases, weeds represented 45% of the ground cover and in the second DAFOR (which ranked only weeds), foxtail, crabgrass, and horse nettle were ranked as dominant, whereas goose grass [*Eleusine indica* (L.) Gaertn.] was ranked as abundant. Other weeds ranked as frequent in switchgrass paddocks included thistles (*Cirsium* spp.) and pigweed (*Amaranthus* spp.).

Chemical Composition of Forages

No differences ($P > 0.05$) in forage CP, NDF, and ADF were detected among systems (Table 3) or among years (data not presented). Differences in the nutritive value of the diet are not always observed when comparing stocking rates. Ackerman et al. (1998) concluded that there was no difference in the nutritive value of the diet of steers managed at 3 stocking rates when grazing Old World bluestem (*Bothriochloa* spp. or *Dichanthium* spp.). However, the nutritive value of the diet consumed by sheep decreased among stocking rates (Jung and Sahlu, 1989). The lack of difference between systems 1 and 2 (different stocking rate and similar grazing method) in the present experiment was probably because stocking rates were not different enough to affect performance. However, differences were observed between periods. The forage available in B-S was greater ($P < 0.05$) in CP and lower in ADF and NDF compared with the other 2 periods (S-W and W-B). This was mainly due to the period of rapid growth during the spring, when all pastures were in the vegetative stage of development.

Hay Production and Feeding

Hay produced and hay fed (Table 4) were influenced ($P < 0.001$) by system and year, but no interaction was detected ($P > 0.50$). Total hay production was greater in system 1 ($P < 0.05$) as a result of the lower stocking rate (Table 4). The lowest ($P < 0.05$) hay production was

Table 3. Nutritive value of forage available by period within system

Period[1]	Fraction[2]	System[3] 1	2	3	4	5	6
W-B	CP	14.8[b]	15.0[b]	13.7[b]	14.6[b]	13.0[b]	15.4[b]
	NDF	57.2[a]	59.3[a]	57.7[a]	57.8[a]	58.7[a]	53.6[a]
	ADF	29.5[a]	32.1[a]	31.0[a]	30.9[a]	32.4[a]	30.0[a]
B-S	CP	23.3[a]	26.0[a]	24.7[a]	25.3[a]	26.7[a]	24.6[a]
	NDF	53.2[b]	51.3[b]	53.3[b]	52.1[b]	53.1[b]	52.2[b]
	ADF	26.8[b]	25.8[b]	26.0[b]	26.2[b]	26.0[b]	26.0[b]
S-W	CP	13.9[b]	16.3[b]	16.7[b]	16.7[b]	14.6[b]	15.7[b]
	NDF	61.7[a]	60.4[a]	59.1[a]	57.2[a]	61.8[a]	60.7[a]
	ADF	34.4[a]	33.4[a]	32.1[a]	32.8[a]	33.8[a]	33.9[a]

[a,b]Within system and nutritive value variable, means without a common superscript letter differ ($P < 0.05$).

[1]W-B = period from weaning to breeding (October to April); B-S = period from breeding to summer (April to July); S-W = period from summer to weaning (July to October).

[2]Fraction: CP was greater (SEM: 4.5), and NDF and ADF (SEM: 6.9 and 4.7, respectively) were lower in period B-S ($P < 0.05$) compared with the other 2 periods.

[3]System: 1 = Middleburg 3-paddock, 0.91 ha/cow, tall fescue (paddock A), tall fescue-clover (paddocks B and C); 2 = Middleburg 3-paddock, 0.71 ha/cow, tall fescue (paddock A), tall fescue-clover (paddocks B and C); 3 = 2 paddocks, 0.71 ha/cow, rotational, tall fescue (paddock A), tall fescue-clover (paddock B); 4 = 3 paddocks, 0.71 ha/cow, rotational, tall fescue (paddock A), tall fescue-clover (paddock B), orchardgrass-alfalfa (paddock C); 5 = Middleburg 3-paddock, 0.71 ha/cow, tall fescue (paddock A), tall fescue-clover (paddock B), switchgrass (paddock C); 6 = Middleburg 3-paddock, 0.71 ha/cow, tall fescue (paddock A), tall fescue-lespedeza (paddock B), tall fescue-birdsfoot trefoil (paddock C).

from system 5 because of the presence of switchgrass in 20% of the area. Although switchgrass has been indicated as suitable for grazing (Burns et al., 1984) or for hay (Vona et al., 1984; Burns et al., 1985), establishment, persistence, and resulting DM production and utilization in the present experiment were poor. Hay production varied ($P < 0.05$) with year (data not shown). In yr 3 and 4, hay production averaged 9,000 kg, whereas an average of only 5,400 kg was produced in yr 1 and 2. As with pasture productivity during yr 3 and 4 (Table 2), increased forage production was strongly related to increased rainfall.

Cow-calf pairs in system 1 were fed the least ($P < 0.05$) amount of hay in the W-B period and the total hay fed was greatest ($P < 0.05$) in system 5 (Table 4). System 1 had the lowest stocking rate, which allowed the greatest amount of herbage available for grazing (Table 2). In contrast, system 5 had greater hay requirements because of the low productivity of switchgrass, which constituted 20% of the area, explaining the higher requirements for hay of this system. The amount of hay fed exceeded the amount produced in the systems in 3 of the 4 yr. Only in yr 3 was more hay produced (9,000 kg) than fed (8,000 kg); hence, hay was purchased outside the systems. However, every bale of hay fed to the animals in a system was attributed to that system. For the 4-yr period of the study, 72% of the hay was fed between weaning and breeding (8,690, 10,300, 6,150, and 8,040 kg for yr 1 through 4, respectively), followed by the period between summer and weaning. The latter was heavily influenced by yr 1, when hay was fed (3,370 kg) because of low forage availability (Table 2).

Table 4. Average amount of hay fed and produced (kg) per system, averaged over the years

Hay fed/period[1]	System[2] 1	2	3	4	5	6	SEM	P-value, S[3]
W-B	6,250[c]	9,130[a]	9,060[a]	7,860[b]	9,700[a]	7,760[b]	415.6	0.001
B-S	40	370	630	90	310	520	202.6	0.319
S-W	1,310[c]	2,190[a]	1,570[bc]	2,280[a]	2,420[a]	1,840[ab]	217.9	0.028
Total hay produced	10,300[a]	7,700[b]	6,700[b]	7,700[b]	4,400[c]	6,900[b]	480.4	0.001
Total hay fed	7,600[d]	11,690[ab]	11,260[b]	10,230[c]	12,430[a]	10,120[c]	745.3	0.033

[a–d]Within a row, means without a common superscript letter differ ($P < 0.05$).

[1]W-B = period from weaning to breeding (October to April); B-S = period from breeding to summer (April to July); S-W = period from summer to weaning (July to October).

[2]System: 1 = Middleburg 3-paddock, 0.91 ha/cow, tall fescue (paddock A), tall fescue-clover (paddocks B and C); 2 = Middleburg 3-paddock, 0.71 ha/cow, tall fescue (paddock A), tall fescue-clover (paddocks B and C); 3 = 2 paddocks, 0.71 ha/cow, rotational, tall fescue (paddock A), tall fescue-clover (paddock B); 4 = 3 paddocks, 0.71 ha/cow, rotational, tall fescue (paddock A), tall fescue-clover (paddock B), orchardgrass-alfalfa (paddock C); 5 = Middleburg 3-paddock, 0.71 ha/cow, tall fescue (paddock A), tall fescue-clover (paddock B), switchgrass (paddock C); 6 = Middleburg 3-paddock, 0.71 ha/cow, tall fescue (paddock A), tall fescue-lespedeza (paddock B), tall fescue-birdsfoot trefoil (paddock C).

[3]System effect.

Table 5. Effect of forage system on cow performance

Item	System[1] 1	2	3	4	5	6	SEM	*P*-value S[2]	Y[3]	S × Y
Cows,[4] n	6	6	6	6	6	6				
Cow performance										
Cow BW, kg										
Breeding (April)	541	528	521	531	526	520	7.5	0.82	0.001	0.51
Summer (July)	543	544	536	545	556	530	14.0	0.85	0.001	0.80
Weaning (October)	554	549	550	563	563	539	16.7	0.89	0.001	0.61
Cow BCS										
Breeding (April)	5.6	4.9	4.9	5.3	4.8	4.9	0.22	0.12	0.001	0.99
Weaning (October)	5.3	4.9	5.0	5.1	4.9	4.6	0.27	0.56	0.002	0.70
Pregnancy rate, %	66.7	85.5	80.6	82.3	84.7	77.8	6.04	0.31	0.001	0.47
Calf:cow BW, kg of calf/kg of cow at weaning	0.435[ab]	0.468[a]	0.429[b]	0.404[c]	0.411[c]	0.452[ab]	0.012	0.02	0.027	0.37

[a–c]Within a row, means without a common superscript letter differ ($P < 0.05$).

[1]System: 1 = Middleburg 3-paddock, 0.91 ha/cow, tall fescue (paddock A), tall fescue-clover (paddocks B and C); 2 = Middleburg 3-paddock, 0.71 ha/cow, tall fescue (paddock A), tall fescue-clover (paddocks B and C); 3 = 2 paddocks, 0.71 ha/cow, rotational, tall fescue (paddock A), tall fescue-clover (paddock B); 4 = 3 paddocks, 0.71 ha/cow, rotational, tall fescue (paddock A), tall fescue-clover (paddock B), orchardgrass-alfalfa (paddock C); 5 = Middleburg 3-paddock, 0.71 ha/cow, tall fescue (paddock A), tall fescue-clover (paddock B), switchgrass (paddock C); 6 = Middleburg 3-paddock, 0.71 ha/cow, tall fescue (paddock A), tall fescue-lespedeza (paddock B), tall fescue-birdsfoot trefoil (paddock C).

[2]System effect.

[3]Year effect.

[4]Number of cows/yr.

No difference ($P > 0.05$) in nutritive value of the hay fed was observed across treatments and across years (data not shown), which may have been because hay was made and fed at the same time across systems. Average CP, NDF, and ADF concentration was 11.2, 70, and 43.4% on a DM basis.

Animal Production

Forage system did not affect any of the cow variables measured (Table 5). A system effect on pregnancy rate was not detected (Table 5) because of the large SE that was observed for this variable, which in turn may be due to the small number of animals per treatment (6 cows/yr), and thus lacked experimental power to detect a 20% difference in pregnancy rates. Across systems, there was an increase in BW from breeding to weaning, although BCS remained the same. Under the conditions of the present experiment, cows were maintained at a moderate condition through the years; thus, a BCS of 5 seems appropriate for adult cows in grazing conditions.

A year effect was present for all response variables measured on cows (data not shown). Except for BCS at weaning, cows weighed more and had greater BCS ($P < 0.05$) in yr 2 as compared with other years. Pregnancy rate (95.4%) was greater ($P < 0.005$) for yr 2 as well. The fact that cow BW and BCS at breeding (561 kg and 5.8, respectively) were greater ($P < 0.05$) could explain at least part of this response (Kunkle et al., 1994). In yr 1 and 2, cows had moderate to good BCS (5.3 and 5.8, respectively) at breeding and lost condition (0.5 point) from breeding to weaning. The decrease in BCS was probably due to the lack of forage available and the fact that fatter cows tend to lose more condition than those in moderate condition (Houghton et al., 1990).

The calf-to-cow weight ratio is considered an accurate predictor of cow-calf biological efficiency (Kress et al., 2001). For systems 2 and 6, this ratio (Table 5) was greater than ratios reported by Coleman et al. (2001), although ratios from the remaining systems in this study were similar. Based on the information reported by Allen et al. (1992), cows weighed approximately 490 kg at weaning (October), whereas calves weighed, on average, 247 kg (range from 238 to 251 kg). This represents a ratio of 0.50, which is greater than the values estimated in this experiment. Another variable important for cow-calf producers is the weight of the calf weaned per unit of land area (kg/ha), which was lowest ($P < 0.05$) for system 1 in the present experiment (Table 6).

The effect of system on calf performance and overall productivity is presented in Table 6. Calf birth weight was not different ($P = 0.76$) across systems. However, system differences were detected in the breeding, midsummer, and weaning weights ($P < 0.003$). Calves in system 2 weighed more than those in all other systems at all 3 times and had a greater adjusted weaning weight ($P < 0.05$). System 2 had the same grazing system and stocking rate as systems 4 and 5, differing in the type of forage in paddock C. Within period, forage nutritive value was not different across systems (Table 3) but forage availability in C paddocks in systems 4 (orchardgrass/alfalfa) and 5 (switchgrass) may have been lower than in system 2, reducing their use as creep-grazing paddocks. Calves did have the option to creep graze in paddocks B and C (adjacent paddocks) in all systems. Creep-grazing time was not measured, but

Table 6. Effect of forage system on calf performance

Item	System[1]						SEM	*P*-value		
	1	2	3	4	5	6		S[2]	Y[3]	S × Y
Calf performance										
Calf BW, kg										
Birth	37	37	36	37	37	37	0.6	0.76	0.15	0.49
Breeding (April)	90[bc]	99[a]	93[b]	85[c]	85[c]	92[b]	2.1	0.001	0.001	0.79
Summer (July)	174[b]	187[a]	175[b]	165[c]	170[bc]	177[b]	3.1	0.002	0.001	0.39
Weaning (October)	240[b]	256[a]	231[bc]	226[c]	231[bc]	243[b]	4.4	0.003	0.01	0.51
Adjusted weaning weight[4]	226[bc]	238[a]	217[bc]	213[c]	220[bc]	226[bc]	4.1	0.01	0.001	0.64
Calf weaned, kg/ha	224[d]	309[a]	281[bc]	268[c]	274[bc]	292[ab]	6.3	0.001	0.01	0.54
Calf weaned adjusted, kg/ha	248[b]	313[a]	307[a]	302[a]	310[a]	319[a]	13.7	0.03	<0.001	0.56

[a–d]Within a row, means without a common superscript letter differ ($P < 0.05$).

[1]System: 1 = Middleburg 3-paddock, 0.91 ha/cow, tall fescue (paddock A), tall fescue-clover (paddocks B and C); 2 = Middleburg 3-paddock, 0.71 ha/cow, tall fescue (paddock A), tall fescue-clover (paddocks B and C); 3 = 2 paddocks, 0.71 ha/cow, rotational, tall fescue (paddock A), tall fescue-clover (paddock B); 4 = 3 paddocks, 0.71 ha/cow, rotational, tall fescue (paddock A), tall fescue-clover (paddock B), orchardgrass-alfalfa (paddock C); 5 = Middleburg 3-paddock, 0.71 ha/cow, tall fescue (paddock A), tall fescue-clover (paddock B), switchgrass (paddock C); 6 = Middleburg 3-paddock, 0.71 ha/cow, tall fescue (paddock A), tall fescue-lespedeza (paddock B), tall fescue-birdsfoot trefoil (paddock C).

[2]System effect.

[3]Year effect.

[4]Adjusted 205-d weaning weight: {[(weaning weight – birth weight)/ weaning age] × 205} + birth weight.

differences in forage consumption from the creep-grazing pastures may have differed between systems. Allen et al. (1992), using a similar breed type and a stocking rate of 0.73 ha/cow, reported weights that were 25 to 40 kg greater than those reported in the present experiment. Similar to system 2, Coleman et al. (2001) reported an adjusted (205-d) weaning weight of 236 kg. Calves were born to Angus-Hereford dams and Charolais, Gelbvieh, Angus, or Hereford bulls. Coblentz et al. (2006) reported similar production responses for cow-calf pairs grazing endophyte-infected tall fescue, although different breeds (Brahman × Angus and Angus dams, and Gelbvieh bulls) were used than those used in the present experiment. Peters et al. (1992) reported an adjusted weaning weight of 212 kg for calves (progeny of Angus and Angus × Simmental cows sired by Angus or Simmental bulls) grazing endophyte-infected tall fescue during 2 consecutive 120-d summer grazing trials, a value that is lower than any of the values reported in the present experiment.

Despite differences in forage management, there was no effect of any of the systems on cow productivity. Year played a major effect on system productivity, denoting the possible variability that can be expected because of environmental conditions. Because weaning weight is the single most important variable in cow-calf systems, an improvement (in nutritive value and quantity) of the forage base available for calves will increase calf gains, and hence increase the total kilograms of beef produced at weaning. Although system 2 was the one with greater animal production, system 1 was the only one that produced enough hay to meet cattle needs.

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